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A Model of Cocoa Replanting and New Planting in Bahia, Brazil, 1966-85

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In Brazil, two decades of high cocoa prices and low interest rates sparked significant growth in new planting of cocoa trees. Higher prices and low interest rates encouraged new planting; but higher prices discouraged replanting in the short term while encouraging it in the long term.

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In 1966, 90 percent of the cocoa growing areas in Bahia, Brazil had trees more than 30 years old. By 1985 most of the area had been replanted or supplied with new trees.

Throughout most of this period there were high or rising cocoa prices — and zero or negative interest rates. High prices and low interest rates directly encouraged new planting,

but their relationship to replanting is more complex. In the short term, higher prices discourage replanting, which involves uprooting and a temporary loss of revenue. But over the long run, higher prices increase expectations of future profits and encourage replanting.

Lowering the interest rate below its real level provided cocoa growers with a subsidy that encouraged both replanting and new planting.

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A MODEL OF COCOA REPLANTING AND NEW PLANTING IN BAHIA, BRAZIL : 1966-1985

I : INTRODUCTION

In 1966 approximately 90 per cent of cocoa growing area in Bahia, Brazil, had trees more than 30 years old. From that date onwards the rate of replanting and new planting grew more or less steadily until about 1980. The average annual replanted and new planted hectarage during 1967-70 was about 731 and 1353 respectively, growing to 1026 and 7800 during the period 1971 to 1975, and rising still further to 4651 and 20841 during 1976-80 before declining to 3510 and 10753 during the last five year period 1981-85. As a result of this remarkable surge in replanting and new planting the ratio of surviving pre-1966 cocoa area to the total planted area was just around 45 per cent in 1985. The purpose of this study is to throw light on the factors that contributed to this post-1966 phase of extra-ordinary growth following the stagnation of the previous two decades.

Analysis of replanting and new planting lies at the heart of the long-term supply response. In the case of perennials the short-term supply elasticity is usually rather small; hence the long-term supply elasticity depends critically on the response of replanting and new planting to price incentives (Nerlove (1979), Binswanger et. al. (1987)). However, given the relative dearth of suitable data on replanting and new planting, such studies are difficult to carry out. The heterogeneity of the planted area and the peculiarities of perennial crop supply create challenges for both theoretical and empirical analysis. To date there has been limited progress in this area, due in large measure to the paucity of data on age-cohorts and

their productivity; see French, King and Minami (1985) and Hartley, Nerlove and Peters (1985) for two recent examples.

Econometric equations for replanting and new planting will be derived from a neo-classical cost of adjustment investment model modified to allow for "vintage effects", viz., differences in the productivity of trees in different age-cohorts. This extends previous analyses. Using available data on new planting and replanting since 1966 and average productivity at different ages, and using the concepts described in Akiyama and Trivedi (1987b), it has been possible to separate the potential output attributable to pre-1966 and post-1966 planted area and to construct measures of productivity on pre-1966 area¹. These measures play an essential role in explaining replanting behavior.

A fundamental difference between new planting and replanting decisions arises from differences in the cost of adjustment. Whereas both involve installation costs, replanting involves uprooting which results in a (temporary) revenue loss whose magnitude depends upon the current and future expected prices and on the average productivity of the uprooted trees. Consequently high and rising prices and productivity tend to encourage new planting and to discourage replanting.

The broad conclusion of the study is that the growth in Brazilian new planting and replanting was a response to high and rising cocoa prices and to zero or negative real interest rates that prevailed for most of our sample period. That is, the evidence is consistent with the behavior implied by the theoretical neo-classical investment model. However, in contrast to

¹ This calculation, sometimes referred to as the vintage matrix method for calculating potential output is described in detail in Akiyama and Trivedi (1987a, 1987b).

new planting, the response of replanting to variation in price is complex. Since the immediate effect of an increase in price is to improve the productivity and profitability of marginal cohorts, which in turn reduces the incentive for uprooting and replanting, replanting is related negatively to price in the short-run; but over the long-term the positive effect of improved profitability dominates the short-term negative effect.

The results of the analysis throw light on the efficacy of certain policies, such as the role of interest subsidies, intended to lead to the rejuvenation of the cocoa sector, and on the prospects for future expansion of this sector in Bahia.

The remainder of this paper consists of the descriptive Section II; Section III sketches the analytical framework; Sections IV and V provide econometric analyses of replanting and new planting respectively; Section VI concludes.

II : A DESCRIPTIVE AND FACTUAL BACKGROUND

We preview some of the major features of replanting and new planting of cocoa in Bahia, Brazil. The area planted under cocoa before 1966 will be referred to as "old area" [OLDAREA]. Further, estimated output or output imputed to this area using the vintage matrix method (based on estimating the separate contributions of new planting and old plantings using average age-yield profiles) will be referred to as "old output" and the estimated production per hectare from the "old area" will be referred to as "old productivity" [OLDPROD].

Planted area and production: Figure 1 shows the log of total cocoa production [LTOTPROD] in Bahia since 1966. Between 1966 and 1971 production was essentially stagnant, but since then it has risen by about 30%. Figure 2 shows log of total area [LTOTAREA] under cocoa. This also has shown considerable growth since 1971, being especially rapid between 1977 and 1981. The total growth in area between 1966 and 1985 has been nearly 40%.

New Planting and Replanting : Between 1946 and 1956 there was very little new planting. Over the next decade the pace increased somewhat, but significant increases in planted area did not occur until after 1966. Figure 3 shows the cocoa new planting hectareage [NPBAH] and NPBAH as a proportion of total planted area [NPBAHR] and as a proportion of old area [NPBAHR2]. The two measures move synchronously. NPBAHR rose from close to zero in 1967 to the peak of 7.4% in 1980 but declined sharply since then to just around 1% in 1985. The peak growth rate of NPBAHR is around 11%.

Figure 4 shows replanting hectareage [RPBAH]. Again note that the most rapid growth in replanting was between 1976 and 1980, and also that, like

new planting, replanting has declined both absolutely and relatively since 1981.

Table 1 shows RPBAH, NPBAH and their respective growth rates for the period 1967-1985. It is clear that new planting and replanting are rather similar in their variability. Figure 5 shows how the ratio of replanting to new planting has varied over the period. From 1968 to 1976 new planting rose, though not steadily, relative to replanting. However, between 1976 and 1984 this tendency was reversed and replanting was almost 40% of new planting in 1984; since 1984 replanting has once again sharply declined relative to new planting.

Age Distribution of Trees : The effect of replanting and new planting undertaken in the last two decades has been a major rejuvenation in the age structure of the cocoa tree stock. Table 2, derived from Knight (1976), shows the estimated age distribution of the Bahia tree stock between 1936 and 1966. Accordingly, nearly 60% of the tree stock in 1966 was more than 40 years old. No estimates are available of the age distribution in the recent years. As a rough index of the average age one may use the ratio of the surviving pre-1966 planted area to total planted area [AGEINDEX]. This is shown in Figure 6. As a consequence of the vigorous new planting and replanting program, AGEINDEX has dropped nearly 60% in just over a decade.

Productivity : Using information on the age distribution of trees planted since 1966, together with estimated age yield profile data for new plantings, the contribution of new planting to total production was separated. By subtraction the contribution of old area can be derived, and

TABLE 1 : Summary statistics on the level and percentage change in new planting and replanting , 1967-1985.

Variable	RPBAH	NPBAH	DLRPBAH	DLNPBAH
Maximum	8788	31568	2.93	2.63
Minimum	449	773	-1.28	-.77
Mean	2572	10651	0.14	0.18
Std. dev.	2465	9098	0.97	0.74

Notes : Figures for RPBAH and NPBAH are in hectares. Those for DLRPBAH and DLNPBAH are annual percentage rates of change for RPBAH and NPBAH, respectively.

Table 2 : Estimated Age Distribution of Productive Cocoa Trees, Bahia, 1936-66

Year	Age group, in years			
	>10 <20	>20 <30	>30 <40	>40
1936	88 (36.8)	60 (25.1)	44 (18.4)	48 (20.1)
1946	116 (32.7)	88 (24.8)	60 (16.9)	92 (25.8)
1956	11 (3.0)	116 (31.6)	88 (24.0)	152 (41.2)
1966	33 (8.3)	11 (2.8)	116 (29.0)	86 (22.0)

Notes: Figures are thousands of hectares and (in parenthesis) percentage of total. Source : Knight (1976).

division by OLDAREA yields OLDPROD. The log of OLDPROD, defined as LOLDPROD , is shown in Figure 7. Compared with the estimates of productivity given by Knight (1973), the yield on OLDAREA shows a dramatic rise from 367 kilos/hectare in 1967/68 to about 990 kilos/hectare in the late 1970's.

The increase in the average productivity of old trees is an important phenomenon. Its source may be partly the increased use of better agricultural practices, including the use of fertilizers, and partly the high real cocoa prices that have prevailed through the 1970's. Figure 8 shows the log of the real cocoa price [LPRICOCO] rising dramatically between 1971 and 1976, and declining between 1976 and 1982 with a partial recovery between 1982 and 1984.

III : ANALYTICAL FRAMEWORK

The analytical framework for empirical analysis is a neoclassical investment model with convex adjustment costs. The model also incorporates a vintage production technology, distinguishes between replanting and new planting. It may be regarded as an extension of the type of model in Nickell (1978) and Hayashi (1982); however, the treatment of uncertainty in our model is still rudimentary.

Notation:

$r(t)$: real discount rate at t net of taxes or subsidies

$\pi(t)$: profit or net revenue

$p_0(t)$: real price of output net of taxes if any

$F[K(t,v),L(t,v);t]$: production function for vintage v capital

$K(t,v)$: stock of capital of vintage v at time t , $t > v$.

$L(t,v)$: labor input combined with capital of vintage v .

$R(t,v)$: uprooting and replanting of vintage v capital at time t

$G[R(t,v),K(t,v)]$: output losses due to removal of vintage v capital

$q(t)$: purchase price of new capital net of grants or subsidies

$C[I_v(t),K(t,v)]$: installation costs of new planting or replanting.

The firm's objective is to maximize the present value of future after-tax net receipts $[\pi(t)]$. The gross revenue function is the difference between the value of total output of production from all economic vintages $[p_0(t)\sum_v F(K(t,v),L(t,v))]$ minus the total wage-bill. The convex function $G(R(t,v),K(t,v))$ denotes adjustment cost, i.e. the output costs associated with investment at rate $R(t,v)$. If $R(t,v)$ is the rate of uprooting and replanting, then $G(.)$ can be regarded as the loss in potential real output

due to the reduction in the productive capital stock. Gross revenue net of adjustment costs is $p_0(t)[F(.) - G(.)] - \text{wagebill}$.

An alternative or an additional cost that may be included in the revenue function is the convex cost of installation associated with new planting, denoted by $C(I(t), K(t, v))$. The total cost of new investment is the sum of the direct cost, denoted by $q(t)I(t)$, and the installation cost $q(t)C(.)$. Therefore, at time t and for vintage v , the net after-tax revenue is equal to the revenue from the output net of "lost output", minus the wage-bill, and minus the direct cost of installation of the investment goods. The decision problem is to choose the time paths of new planting and replanting and labor input to maximize the present value of net after-tax receipts, given the time-paths of prices of all inputs and output, the technology and the capital accumulation equation.

Since the general solution to this decision problem is complex, or even intractable, important simplifying assumptions are made. It will be assumed that a firm is either replanting (uprooting and then replacing) or undertaking new planting, but does not simultaneously undertake both activities. This allows us to ignore the complication arising from possible interdependence in the cost of adjustment associated with the two types of activities.² It also enables us to develop the view-point that the essential difference between new planting and replanting as ways of expanding productive capacity lies in the different costs of adjustment associated with each. Specifically, it is suggested that replanting is different from new planting because it involves higher output losses in

² While it is difficult to judge the realism of this assumption for the Bahia cocoa data, it will be a reasonable assumption if new planting and replanting is undertaken by distinctly different groups of farmers.

addition to installation costs.

The net revenue function for vintage v trees in period t is

$$\pi(t,v) = p_0(t)\{F[K(t,v),L(t,v)] - G[R(t,v),K(t,v)]\} - w(t)L(t,v) - q(t)I(t) - q(t)C[I(t),K(t,v)] \quad (1)$$

where the first term on the right-hand side is the revenue net of output loss due to replanting (if any), the second term is the wage-bill, the third term is the purchase cost of new capital, and the final term is the installation cost of newly purchased capital.¹ In the case of replanting the last term will be omitted since no purchase of new capital (i.e. land is involved). In the case of new planting only the output loss function $G[.]$ will be omitted since no loss of potentially productive land is then involved. It is assumed that the functions $F[.]$, $G[.]$ and $C[.]$ are linear homogeneous in their arguments. Further, the production function satisfies conventional regularity conditions in that the marginal product of "mature" capital is positive and exhibits diminishing returns. $G[.]$ and $C[.]$ are convex cost functions such that $G[.] \geq 0$ as $R(t,v) \geq 0$, $G_R[.] > 0$, $G_{RR} < 0$, $C[.] \geq 0$ as $I(t) \geq 0$, $C_I[.] > 0$, $C_{II} < 0$.

Firm's total profit over all productive vintages is given by

$$\pi(t) = \sum_v \pi(t,v), \quad v \in V^* \quad (2)$$

where V^* is the set of currently economic (and hence productive) vintages.

The stock of vintage v capital is given by

$$K(t,v) = K(t-1,v) - R(t,v) \quad (3)$$

which assumes for simplicity that depreciation is zero and that there are no exogenous unplanned losses.

Capital stock of vintage v capital, $K(t,t)$ is given by

$$K(t,t) = I(t) = I_v(t). \quad (4)$$

By definition, replanting means removal of uneconomic vintage v capital and replacement by trees of current vintage. That is, if the replanting option is chosen then²

$$I_v(t) = R(t, v). \quad (5)$$

For convenience of exposition assume that the firm replanting and new planting decisions can be analyzed separately. This implies restrictions on the structure of adjustment costs.

Define the Lagrangean function

$$\begin{aligned} H(t, v) = & \pi(t, v) + l(t, v)[K(t, v) - K(t-1, v) + R(t, v)] \\ & + \mu(t, v)[I_v(t) - R(t, v)] \end{aligned} \quad (6)$$

where $\{l(t, v), \mu(t, v)\}$ are families of lagrange multipliers which may be interpreted respectively as the shadow prices of vintage v capital and current capital replacing $R(t, v)$. The firm's decision problem is to choose either the replanting sequence $\{R(t, v)\}$ or new planting sequence $\{I_v(t)\}$ so as to unconstrainedly maximize the value of

$$W = E[\sum_s r(t+s)H(t+s) | \Omega(t-1)] \quad (7)$$

where E denotes the operation of taking conditional expectations given the information set $\Omega(t-1)$ at $t-1$ and the vintage v subscript is omitted for notational convenience. Because the objective is to motivate behavioral equations for aggregative analysis an interior solution is assumed and corner solutions ignored. The necessary conditions for maximization (the Euler equations) are as follows:

$$E_{t-1}[p_0(t+s)F_L(t+s) - w(t+s)] = 0 \quad (8)$$

$$\begin{aligned} E_{t-1}[p_0(t+s)F_K(t+s) - G_K(t+s) - q(t+s)C_K(t+s) + l(t+s) \\ - r(t)l(t+s+1)] = 0 \end{aligned} \quad (9)$$

$$E_{t-1}[-p_0(t+s)G_R - \mu(t+s) + l(t+s)] = 0 \quad (10)$$

$$E_{t-1}[-q(t+s) - q(t+s)C_I + \mu(t+s)] = 0. \quad (11)$$

In the Euler equations F_L , F_K , G_R , C_I , and C_K denote the first partial derivative of the respective functions with respect to the subscripted variable. (These derivatives may themselves be separable functions of time but this feature is omitted here for convenience).

Eliminating $\mu(t+s)$ from (10) and (11) yields

$$l(t+s) = E_{t-1}[p_0(t+s)G_R + q(t+s) + q(t+s)C_I] \quad (12)$$

where the right-hand side is the expected marginal cost of replanting. Assuming now a constant real discount rate, say r , from (9) solve for $l(t+s)$ to obtain

$$l(t+s) = E_{t-1}[\sum_s r^s [p_0(t+s)(F_K - G_R) - q(t+s)C_K]] \quad (13)$$

where the right-hand side is the expected discounted present value of the marginal revenue product of capital net of adjustment costs of capital.

Eliminating $l(t+s)$ from (12) and (13) yields the basic equation from which one may derive the replanting and new planting equations, viz.

$$E_{t-1}\{p_0(t+s)G_R + q(t+s)(1+C_I)\} = \sum_s r^s \{p_0(t+s)(F_K - G_R) - q(t+s)C_K\} \quad (14)$$

which can be regarded as a generalization of the familiar condition from the adjustment cost models of investment in which the optimal rate of investment is given by the equality of the marginal cost and present value of benefits of investment.

The desired investment equation is a closed form solution to this equation. However, such a closed form solution can only be derived after imposing restrictions on the form of the production function and the adjustment cost function and making strong assumptions about the expected time path of prices. Specifically, a necessary condition is that the production function is homogeneous and that the adjustment cost function is

homogeneous and quadratic, (Nickell (1978)). Given these assumptions the above equation can be solved for $I(t)/K(t,v)$.

Linear homogeneity implies that the first partial derivatives are functions of the ratios of their respective arguments, viz., K/L , or I/K or R/K . A further assumption is that the functions G and R are quadratic in their arguments such that the partial derivatives G_R , C_I are linear functions of their arguments. That is, for each vintage v ,

$$G_R(t+s) = \alpha_0 + \alpha_1(R(t+s)/K(t+s)) \quad \alpha_0, \alpha_1 > 0 \quad (15a)$$

$$G_K(t+s) = \beta_0 - \beta_1(R(t+s)/K(t+s)) \quad \beta_0, \beta_1 > 0 \quad (15b)$$

$$C_I(t+s) = \tau_0 + \tau_1(I_v(t)/K(t+s)) \quad \tau_0, \tau_1 > 0 \quad (15c)$$

$$C_K(t+s) = \delta_0 - \delta_1(I_v(t)/K(t+s)) \quad \delta_0, \delta_1 > 0 \quad (15d)$$

Combining (15a)-(15d) and (14) yields

$$E_{t-1}\{p_0(t+s)(a_0 + a_1(R(t+s)/K(t+s))) + q(t+s)(1 + c_0 + c_1(I_v(t+s)/K(t+s))) = \Sigma_s r^s [p_0(t+s)(F_K - G_K) - q(t+s)(d_0 + d_1(I_v(t+s)/K(t+s)))]\}. \quad (16)$$

To derive an equation for $R(t+s)/K(t+s)$, set $R(t+s) = I_v(t+s)$, omit the term $q(t+s)$ from the right-hand side and solve (16) for the replanting ratio $R(t+s)/K(t+s)$. Under the stated assumption of linear homogeneity of F , F_K along the optimal path will be a function of relative prices alone. Even with these assumptions a closed form solution for R/K seems unlikely to be obtained.

To derive the equation for $I_v(t+s)/K(t+s)$, the same approach may be followed, omitting the terms involving G . In this case (16) simplifies to

$$E_{t-1}\{q(t+s)(1 + \tau_0 + \tau_1(I(t+s)/K(t+s))) = \Sigma_s r^s [p_0(t+s)F_K - q(t+s)(\delta_0 + \delta_1(I(t+s)/K(t+s)))]\} \quad (17)$$

which may be readily solved for $I_v(t+s)/K(t+s)$.

For empirical analysis the model needs modification. For the replanting

equations we need to modify $G[\cdot]$ and $C[\cdot]$ to reflect the effects of relevant exogenous variables. Specifically add to the right-hand side of (15a) and (15b) a term involving the average productivity of capital. In general this is of course endogenously determined. However, under the assumption that tree-crops display a typical biologically determined pattern of productivity change, the output loss associated with the reduction in capital due to replanting would be related systematically to the average product of capital for that vintage. In many cases, the older the vintage the lower will be the loss of output due to replanting. Let $PROD$ denote average productivity. Then modify (15a) to

$$G_R(t+s) = \alpha_0 + \alpha_1(R(t+s)/K(t+s)) + \alpha_2 PROD(t+s), \quad \alpha_2 > 0, \quad (18)$$

which may be further modified to

$$G_R(t+s) = \alpha_0 + \alpha_1(R(t+s)/K(t+s)) + \alpha_2(t+s)(PROD(0)), \quad (18a)$$

if $PROD$ has a profile that depends upon age alone.

The function C_I may also be modified to take into account exogenous variables such as implicit or explicit replanting and/or new planting subsidies designed to affect the adjustment. Denoting by Z_2 the set of such variables, (15c) may be rewritten as follows:

$$C_I(t+s) = \tau_0 + \tau_1(I_v(t+s)/K(t+s)) + \tau_2 Z_2. \quad (19)$$

Consider some modifications of the right-hand side of (16), interpreted as the expected net discounted marginal productivity of investment, referred to as MER for brevity. This depends upon the time-paths $\{p_0(t+s), q(t+s), w(t+s)\}$ and also on the discount rate r . Separate and distinct expectational assumptions about the time-paths of prices will lead to an empirically intractable model. More simply, write the $MER(t+s)$ function in terms of average revenue per unit of capital, denoted by $AR(t+s)/K(t+s)$ and the

discount rate $r(t+s)$:

$$MER(t+s) = E_{t-1} [\Theta_0 + \Theta_1 (AR(t+s)/K(t+s)) - \Theta_2 r(t+s)] . \quad (20)$$

The assumption of linearity is rather special, though similar assumptions have been made in the so-called Q-theory investment literature. Such a specification implies that the firm takes a short-cut by forming expectations directly in terms of revenue rather than separately for its components. Finally substitute the above assumptions into (16) and solve for $R(t+s)/K(t+s)$ or $I(t+s)/K(t+s)$. The replanting equation is :

$$\begin{aligned} [(\alpha_1 p_0(t+s) + \tau_1 q(t+s))(R(t+s)/K(t+s))] = E_{t-1} \{ & -\alpha_0 p_0(t+s) \\ & - \alpha_2 PROD(t+s) - \tau_2 q(t+s) Z_2(t+s) + \Theta_0 + \Theta_1 (AR(t+s)/K(t+s)) \\ & - \Theta_2 r(t+s) \} \end{aligned} \quad (21)$$

The price variables enter this equation in a multiplicative fashion. A linearized version of this equation is

$$\begin{aligned} R(t+s)/K(t+s) = E_{t-1} \{ & -A_1 p_0(t+s) - A_2 q(t+s) - A_3 PROD(t+s) \\ & - C_2 Z_2(t+s) + D_1 (AR(t+s)/K(t+s)) - D_2 r(t+s) \} \end{aligned} \quad (22)$$

where all coefficients are positive a priori. Thus the replanting rate is negatively related to the expected output price, the price of new capital and the real interest rate and positively to the expected average revenue. The new planting equation is simpler since the terms arising from $G[.]$ do not appear. Thus we have

$$\begin{aligned} I(t+s)/K(t+s) = E_{t-1} \{ & -B_1 q(t+s) - B_2 Z_2(t+s) + B_3 (AR(t+s)/K(t+s)) - \\ & B_4 r(t+s) \}. \end{aligned} \quad (23)$$

Aggregation : The derivations given above apply to planting rates relative to the stock of a single vintage, i.e., the cohort of trees planted in any one year. Thus the replanting rate would be the proportion of trees in that cohort that are replanted (compare French, King and Minami (1985)).

New planting could be defined relative to the size of any cohort. But data constraints are likely to lead to aggregation of vintages. The criteria for aggregation are likely to be case dependent. However, the use of broad age classes has pragmatic appeal. Further, under average conditions productivity may vary systematically with age. It seems natural in such cases to aggregate across all age cohorts greater than (say) X years as if these were acceptably homogeneous. The replanting rate is sometimes defined as total replanting as a proportion of all area older than X years. This assumes that replanting have not occurred in younger cohorts³. Given suitable data, separate replanting rate for each age-class may be considered⁴. In the case of new plantings it is not obvious which aggregate stock of capital should be used to define the rate of new plantings⁵.

³ French, King and Minami (1985) provide examples to the contrary.

⁴ Often data may be available only on total replanting but it may be possible to separate the capital stock into at least two age classes, say pre- and post-year Y. This will provide an opportunity for estimating equations with different dependent variables.

⁵ One obvious alternative is to exclude only the immature vintages. A narrower aggregate is obtained by taking all vintages considerably older than even the mature vintages. Since the choice is arbitrary an econometric sensitivity analysis seems desirable.

IV : AN ECONOMETRIC MODEL OF REPLANTING

The starting point of empirical analysis is the first-order condition for revenue maximization which states that the rate of investment must be such as to equalize the present value of net marginal expected revenue (MER) from additional investment and the marginal cost of investment (MCI). For exposition, write this in the form

$$\text{MER}(I(t), K(t, v); Z_1) = \text{MCI}(I(t), K(t, v); Z_2). \quad (24)$$

It is possible that the variables Z_2 in the new planting and replanting equations are different.

Specification of MER(.) function

(1) MER per unit of investment is increasing in the expected net marginal revenue product of capital. Given constant returns to scale the latter can be expressed as a function of expected future taxes, wage rates and product prices. But a separate specification for each of these, leading to an average or marginal revenue specification, will lead to an overparametrized model. A simpler approach is to specify an equation for expected revenue directly.

Accordingly it will be assumed that firms base their decisions on forecasts of gross revenue per unit capital and that the expected gross marginal revenue product per unit of investment is linear in expected average gross revenue which in turn is a linear function of lagged average gross revenue.

(2) A priori $G(.)$ is quadratic and homogeneous and has a positive first derivative with respect to $I(t)/K(t, v)$. A higher rate of replanting implies an initially smaller capital stock and higher immediate costs of "lost output", for a given price of output. Marginal net revenue product of

a unit of replanting is decreasing in the real value of "lost output", which in turn is increasing in the expected real price of cocoa. For any given age structure of capital, high expected future price implies a future demand for a larger productive stock and a corresponding higher present opportunity cost of replanting.

(3) The marginal product of scrapped capital is endogenously determined. Economic age of capital is also endogenous. But biologically-determined age-related changes in the productivity of capital stock introduces an exogenous component. For example, productivity may decline monotonically after certain age, say 40 years. Then the marginal value of "lost output" due to replanting will be a decreasing function of the age of the scrapped capital. Such a dependence could be captured by making expected losses in revenue depend upon an index of age, e.g. AGEINDEX mentioned in an earlier section.

An alternative specification would include a variable reflecting the (unobservable) average productivity of marginal capital, i.e. capital that earns zero quasi-rents, see Hartley, Nerlove and Peters (1986). Here it will be assumed that the average productivity of marginal capital is linear in the average productivity of the "old capital", i.e pre-1966 stock of trees. A priori, "lost output" is positively related to OLDPROD; hence, the rate of replanting will be negatively related to OLDPROD.⁶

(4) The expected marginal revenue is a decreasing function of the discount rate. The higher the discount rate used in the calculation of marginal expected revenue, the lower will be the expected revenue associated

⁶ Average measured productivity will generally include a component which responds to price movements.

with replanting.

Specification of MCI(.) function

(5) The standard convex, quadratic and homogeneous formulation of $C[.]$ is modified by including the multiplicative variable $I(t)/K(t,v)*RSUBRATE$ in the cost function, where $RSUBRATE$ is intended to account for the real subsidies per hectare given for replanting. The specific subsidy effect modelled this way is the interest rate subsidy given by CEPLAC to cocoa producers in the period 1979 to 1985⁷. A priori, the partial derivative of $C[.]$ with respect this variable is negative, reflecting the reduction in marginal installation costs due to replanting subsidies.

(6) Adjustment cost models typically specify the marginal adjustment costs to be $q + C_1$, where q is the unit purchase price. However, since no such direct cost of purchase of land is involved for the replanting producer, it may be omitted in our model of replanting but should be included in the model of new planting.

Linearizing equation (24) yields :

$$r_0 + r_1 GREVE - r_2 REALINT - r_3 PRIE - r_4 OLDPROD - r_5 RPBAHR2 = \\ c_1 + c_2 RPBAHR2 - c_3 RSUBRATE + ERROR \quad (25)$$

where

GREVE : expected gross revenue per replanted unit of capital

REALINT : real interest rate as proxy for the discount rate

PRIE : expected real cocoa price

OLDPROD : estimated average productivity (MT/HA) on OLDAREA

RSUBRATE : real subsidy rate for replanting.

RPBAHR2 : replanting divided by OLDAREA

⁷ CEPLAC memo; October 1987.

All coefficients are positive a priori.

Since this still involves unobservables additional simplifying assumptions are required to obtain the final estimating equations in terms of observables. GREVE is proxied by either a second-order autoregression on two past values of the variable AREVPROD, which measures gross revenue per unit of old capital, or more restrictively by a two-period moving average of AREVPROD.

$$\text{GREVE}(t) = a_1 \text{AREVPROD}(t-1) + a_2 \text{AREVPROD}(t-2)$$

We require a measure of expected after-tax revenue on replanted area whereas AREVPROD measures average pre-tax revenue on OLDAREA. For present purposes this will be defined as the measure of real gross revenue per hectare of old area [AREVPROD] as the product of PRICOCO and OLDPROD, where PRICOCO is real price per kilo of cocoa beans, and OLDPROD is the yield per hectare. For some purposes this calculation is deficient. First, the calculation of OLDPROD includes even area which may be currently uneconomic to harvest. Therefore, AREVPROD understates the revenue per unit of harvested area. Second, the measure of operating costs excludes the imputed cost of services of land which is theoretically relevant. Third, the direct costs of acquiring new land are ignored. However, this is not necessarily a serious problem if one wishes to use AREVPROD to explain replanting and it also happens to be the case that replanting and new planting are undertaken by essentially different enterprises. To the replanters the cost of new land is not a part of the costs of production and should be excluded. To the new planters who will necessarily face such a cost, AREVPROD will overstate the average revenue per hectare of old area. Its behavior is of course heavily correlated with that of PRICOCO which has a direct effect and an indirect

effect through OLDPROD. Excluding taxes is not serious since the producer taxes have been static for the Bahia cocoa producers. Perhaps revenue on newly planted area may provide a better surrogate variable. On the other hand, it can also be argued that the relevant expectations may be those based on the past experience of those currently replanting rather than those engaged in new planting. This would justify the use of AREVPROD.

Analogously, PRIE will be proxied by either last period's price, denoted PRICOCO(t-1) or by a moving average of two past prices, denoted MAPRI. This, of course, is a very simple assumption⁸. However, the Dickey-Fuller did not reject the hypothesis that PRICOCO is first order autoregressive with a unit root, which suggests that the "naive" forecasting rule assumed here is actually the optimum rule.

Combining the assumptions yields the following basic replanting equation :

$$\begin{aligned} \text{RPBAHR2}(t) = & d(r_0 - c_0) + dr_1 a_1 \text{AREVPROD}(t-1) + dr_1 a_2 \text{AREVPROD}(t-2) - \\ & dr_2 \text{REALINT}(t-1) - dr_3 b \text{PRICOCO}(t-1) - dr_4 \text{OLDPROD}(t-1) \\ & + dc_3 \text{RSUBRATE}(t) \end{aligned} \quad (26)$$

where $d = 1/(c_1 + r_4) > 0$.

In summary, the rate of replanting can be expected to rise when average revenue on existing area has been rising, and when the real subsidies are increased, but will tend to fall when the real interest or the real producer price of cocoa or the productivity of existing area rises.

⁸ However, using the arguments given elsewhere [see Akiyama and Trivedi (1987)] it would appear that the relevant model of world cocoa price determination is likely to be complex in terms of its informational requirements and a simpler assumption such as that which made above has appeal in terms of the acknowledgement of the limited informational resources available to the cocoa producers.

The Results

The estimates of the basic equation estimated for 1968-85 without the subsidy variable RSUBRATE are given in Table 3, the variant with the subsidy variable is in Table 4. All coefficients are well-determined and have a priori expected signs, with the exception of AREVPROD(-2). The fit of the equation as judged by the R-Bar squared coefficient, the absence of serial correlation and heteroscedasticity in the residuals and the diagnostic test of the functional form, is good, perhaps surprisingly so. The graph of predicted vs. actual values for the dependent variable shows no significant episodes

TABLE 3 : Basic Replanting Equation

Dependent variable is RPBAHR2
18 observations used for estimation from 1968 to 1985

Regressor	Coefficient	T-Ratio
CONS	.0295	4.6063
AREVPROD(-1)	$.1995 \times 10^{-3}$	6.8853
AREVPROD(-2)	$.0022 \times 10^{-3}$.3235
REALINT(-1)	$-.2452 \times 10^{-3}$	-5.3344
PRICOCO(-1)	$-.1152 \times 10^{-3}$	-6.2994
OLDPROD(-1)	-.0492	-4.6606
R-Squared	.9664	
F-statistic F(5, 12)	69.0101	
R-Bar-Squared	.9524	
S.E. of Regression	$.2038 \times 10^{-2}$	
Residual Sum of Squares	$.0498 \times 10^{-3}$	
Mean of Dependent Variable	.00920	
S.D. of Dependent Variable	.00934	
DW-statistic	2.1109	

Diagnostic Score (LM) Test Statistics

A:Serial Correlation	CHI-SQ(1)=	0.2632
B:Functional Form	CHI-SQ(1)=	2.3738
C:Normality	CHI-SQ(2)=	1.3139
D:Heteroscedasticity	CHI-SQ(1)=	.0562

Notes :

A:Lagrange multiplier test of residual serial correlation

B:Ramsey's RESET test using the square of the fitted values

C:Based on a test of skewness and kurtosis of residuals

D:Based on the regression of squared residuals on squared fitted values

unexplained by the regression. The leverage chart shows that most of the explanatory power of the regression derives from post 1977 data. As was noted earlier this coincides with the period of most rapid growth in replanting⁹.

As a part of the diagnostic checking of the equation tests of parameter stability based on the CUSUM and CUSUMSQ of the recursive residuals were also carried out and these also indicated that the basic equation was satisfactory. Figures 9-12 provide plots of the coefficients of significant variables based on recursive regression¹⁰. These plots show considerable stability in the signs of the coefficients post 1976.

Comparison with some variants: Before turning to an analysis of the policy implications of the results it is useful to compare the basic equation with some of the variants. In one two-period moving averages of PRICOCO and OLDPROD were used in place of the one-period lagged values; in another the surrogate variable AGEINDEX was substituted in place of OLDPROD. In yet another only one of the two variables REALINT and REALSUB was tried.

First, consider the role of subsidies on interest payments of the replanters¹¹. Observe from Figure 13 that RSUBRATE and REALINT were strongly negatively related over the period of subsidy. Note that the period over which the subsidies were given was quite short compared with the sample

⁹ The results were less satisfactory when the dependent variable RPBAHR was used, which again suggests that deflation by OLDAREA rather than TOTAREA is more appropriate.

¹⁰ See Dufour (1982) for a survey of recursive regression techniques for the regression model. The calculations reported here were executed using DATAFIT program by Pesaran and Pesaran (1987).

¹¹ The figures for interest rate subsidies were provided by CEPLAC.

period. The rate of subsidy rose as REALINT fell sharply from 1977 to 1980, and fell as REALINT rose sharply between 1981 and 1985. This strong negative correlation, in conjunction with the absence of substantial variation in REALINT before 1975, makes it very difficult to separate the individual effects of the two variables. It is clear from Table 4 that REALSUB does have a strong effect on the rate of replanting provided REALINT(-1) is excluded from the equation. Nevertheless, since the diagnostic tests of the resulting equation show evidence of both serial correlation and heteroscedasticity, and, moreover, the coefficients in this variant are not uniformly precisely determined, the basic equation of given earlier seems preferable. To confirm this preference for the basic equation, non-nested hypothesis tests were run to compare the two variants. The results given in Table 5 generally favor the specification with REALINT(-1) over that with RSUBRATE. It is emphasized that even though the REALINT specification is favored, the available evidence is consistent with the hypothesis that the interest rate subsidies given by CEPLAC stimulated replanting.

Now consider the specifications based on two-period moving averages of PRICOCO and OLDPROD, denoted, respectively, by MAPRI and MAOLDPR. The estimated equation had sharply determined coefficients, but provided no improvement in the overall fit of the model. Actually there is a slight deterioration. Once again the basic specification is favored by the non-nested tests given in Table 6 though the margin of improvement offered by the basic model is slight.

Finally, consider the choice between two possible determinants of "lost output", AGEINDEX and OLDPROD. When AGEINDEX(-1) is substituted in place of

TABLE 4 : Replanting Equation with Subsidy Variable

Dependent variable is RPBAHR2

18 observations used for estimation from 1968 to 1985

Regressor	Coefficient	T-Ratio
CONS	.0069743	1.1821
AREVPROD(-1)	.0828x10 ⁻³	2.9185
AREVPROD(-2)	-.0057x10 ⁻³	-.6038
RSUBRATE	.1194x10 ⁻²	4.1312
PRICOCO(-1)	-.0366x10 ⁻³	-1.8451
OLDPROD(-1)	-.9990x10 ⁻²	-1.0819
R-Squared	.9532	
F-statistic F(5, 12)	48.9066	
R-Bar-Squared	.9337	
S.E. of Regression	.0024	
Residual Sum of Squares	.0694x10 ⁻³	
Mean of Dependent Variable	.0092	
S.D. of Dependent Variable	.00934	
DW-statistic	2.7985	

TABLE 5 : Tests for Non-Nested Regression Models

Dependent variable is RPBAHR2

Regressors for model M1: CONS, AREVPROD(-1), AREVPROD(-2),
RSUBRATE, PRICOCO(-1), OLDPROD(-1)Regressors for model M2: CONS, AREVPROD(-1), AREVPROD(-2),
REALINT(-1), PRICOCO(-1), OLDPROD(-1)

Test Statistic	M1 against M2	M2 against M1
COX-PESARAN TEST	-4.0023	-1.3238
ADJUSTED COX-PESARAN	-3.0145	-.9773
DAVIDSON-MACKINNON J-Test	2.3284	.8935
ADJUSTED J-Test	2.3284	.8935

Model M1: DW 2.7985 ;R-Bar-Squared .9337

Model M2: DW 2.1109 ;R-Bar-Squared .9524

Akaike's Information Criterion of M1 versus M2= -2.9756
favours M2

TABLE 6 : Tests for Non-Nested Regression Models of Replanting

Dependent variable is RPBAHR2

Regressors for model M1: CONS, AREVPROD(-1), AREVPROD(-2),
REALINT(-1), MAPRI, MAOLDPR

Regressors for model M2: CONS, AREVPROD(-1), AREVPROD(-2),
REALINT(-1), PRICOCO(-1), OLDPROD(-1)

Test Statistic	M1 against M2	M2 against M1
COX-PESARAN TEST	-2.5758	-1.4636
ADJUSTED COX-PESARAN	-1.8761	-1.0374
DAVIDSON-MACKINNON J-Test	1.6607	1.0080
ADJUSTED J-Test	1.6792	.9518

Model M1: DW 1.9375 ;R-Bar-Squared .9459 88.4834

Model M2: DW 2.1109 ;R-Bar-Squared .9524 89.6325

Akaike's Information Criterion of M1 versus M2 = -1.1491 favours M2

OLDPROD(-1), there was significant deterioration in the fit of the model, though all coefficients retained their a priori expected signs. The non-nested model test comparisons unequivocally support the basic specification over the alternative.

Hence the regression model of Table 3 is suitable for summarizing the contribution of the four determinants to changes in the rate of replanting (RPBAHR2). The changes were generally positive between 1975-1981 and generally negative subsequently. In the post-1975 period the contribution of the revenue factor has been generally negative, the exceptions being the years 1977, 1978 and 1984. The contribution of the real interest factor was positive from 1980-1982 and since then generally negative.

Over the sample period cocoa price has shown very sharp fluctuations and hence its contribution to replanting has also shown corresponding sharp variations. This contribution was large and negative in 1977 and 1978, but positive between 1979 and 1983. That is, while the revenue factor was tending to lower replanting, the lower real cocoa price tended to encourage it. To the extent that the two effects are in opposite directions the total price elasticity of replanting can be theoretically quite low and theoretically even negative when one takes into account the effect of increase in the price on the productivity of old area.

Average productivity on old area has been rising for most of the sample period, quite possibly stimulated by price increases. The contribution to replanting from improvements in productivity is positive to the extent that it improves revenue but negative to the extent that it raises the opportunity cost of replanting. The latter factor has had a negative impact throughout most of the sample period.

Elasticity of RPBAH with respect to PRICOCO

The total elasticity of replanting with respect to PRICOCO depends upon (i) the (negative) direct effect of PRICOCO on replanting, (ii) the (positive) effect operating through the revenue variable and (iii) the (negative) effect operating through the productivity variable. Since the first effect operates with shorter lags than the other two, it determines the short-term elasticity which is found to be -4.4. The revenue variable adds nearly 7.4 to this figure whereas improvement in price which causes the average yield to rise contributes -1.3. Combining the three estimates produces a total elasticity of about 1.7¹².

The result that the short-term price elasticity is negative and sizeable serves to emphasize the importance of the endogenous element in scrapping and harvesting decisions (see Trivedi (1987)). An increase in the real price of cocoa will encourage producers to operate at the extensive margin of production by increasing the economic life of all existing capital including capital which was previously uneconomic, thus reducing the rate of uprooting/replanting. Higher prices also encourage the producers to raise yields on all existing capital and this tends to depress replanting. For the present data set these two negative effects are found to be substantial but do not dominate the positive effect of the revenue variable. This last effect is not only statistically significant on its own, but it determines the sign of the total effect.

¹² Of course such an estimate is subject to the usual estimation error which may be considerable in the present small sample. Further recall that theoretical arguments suggest a nonlinear response to price changes so that in any given instance the response of replanting may differ substantially from that estimated from a small sample.

Interest rate effects

The partial derivative of replanting with respect to the real interest rate is negative and highly significant statistically¹³. The change in interest rate has been of the order of fifty percentage points in some years, e.g. 1980, and this implies a reduction in replanting of about 4035 ($= 0.2452 \times 10^{-3} \times 50 \times 329189$) hectares. Comparison with the data in Table 1 shows this to be a large effect. Clearly, real interest subsidies can be expected to have significant stimulatory effects.

¹³ The interest rate elasticity calculated at the sample mean real interest rate of about -15% (see Figure 21) is positive at about 0.48. Since the real interest rate has fluctuated between positive and negative values the elasticity value as such is not very meaningful.

V : ECONOMETRIC ANALYSIS OF NEW PLANTING

The new planting equation is derived in a manner similar to that for replanting, but the specification of the costs of adjustment is different¹⁴. New planting decisions are based on expected profit calculations. In estimating expected gross revenue the operating costs and average yield at maturity should be those which apply to the variety being considered. It is likely that the average yield at maturity of newly planted areas may be substantially different from the yield on older areas due to differences in soil fertility, chosen varieties and the average age of planted area. Despite this the first alternative considered for proxying expected revenue of new planting is AREVPROD. Again two lagged values of AREVPROD are used to proxy GREVE. The major justification for this is that, given the relative unimportance of new planting before 1966, and the rather low level of new planting until 1975, reliable estimates of the revenue of new planting based on the yield of newly planted area cannot be formed except for a rather small part of our sample. Estimation based on such a small sample will not yield useful results. On the other hand, it is at least plausible that the movements in the revenue of newly planted areas should closely mirror the movements in revenue of the older areas since both depend to some extent on PRICOCO.

Yet another possibility is to specify expected revenue to be a linear function of two lagged values of PRICOCO. Such a specification ignores an important component of revenue, viz. average yield, but could involve a relatively smaller error than using AREVPROD variable if the past yield on

¹⁴ It may be argued also that the relevant measure of expected revenue also should be different.

OLDAREA does not properly reflect the expected future yield on new area.

Specifically, it is assumed that new planting does not involve any "lost output", i.e., the $G(.)$ function does not appear in the specification of the net revenue function. Consequently, the variables $PRIE$ and $OLDPROD$, whose inclusion in the replanting equation was justified through their relationship with the "lost output", will not appear in the new planting equation.

Adjustment costs enter the model only through the installation cost function $C(.)$. However, we allow $C(.)$ to include a dynamic element in the following sense. For a static convex installation cost function, $C_1 > 0$. In the case of perennial, where inelastic supply of suitable land even in the long run may constitute a constraint, adjustment costs will also rise over time as the supply of suitable land is depleted. The latter cost is external to the firm and will be reflected in the rising purchase price of capital. As, however, we do not have data on the price of suitable cocoa-growing land a proxy variable for the speed of depletion of suitable land is included; viz., the total "newly installed capacity". The higher the ratio of "newly installed capacity" to total capacity, the higher will be the marginal installation cost of any further additions. To apply this idea one needs an operational definition of "newly installed".¹⁵

Since interest rate subsidies which apply to replanting are not available for new planting, no subsidy variable will appear in the new planting equation.

The first order condition for profit maximization for new planting is

¹⁵ Here the capacity added after 1966 will be referred to as "new capacity".

that the present value of marginal expected revenue from new planting should equal its marginal installation cost¹⁶. As before a linear MER function is specified in the variables AREVPROD(-1), AREVPROD(-2), and REALINT. The marginal installation cost is also linear in PLAND which is the empirical counterpart of the theoretical variable q; the rate of new planting as measured by either NPBAHR or NPBAHR2 and a variable measuring the ratio of "newly installed capacity" to old capacity or total capacity, measured by either KNPLR, KNPLR2 or NEWCAPR2. Thus we have

$$\begin{aligned} & r_0 + r_1 \text{AREVPROD}(t-1) + r_2 \text{AREVPROD}(t-2) - r_3 \text{REALINT}(t) \\ & = \text{PLAND}(t) + c_0 + c_1 \text{NPBAHR}(t) + c_2 \text{KNPLR}(t-1) \end{aligned} \quad (27)$$

Rewriting gives an equation for new planting :

$$\begin{aligned} \text{NPBAHR}(t) &= d(r_0 - c_0) + dr_1 \text{AREVPROD}(t-1) + dr_2 \text{AREVPROD}(t-2) \\ &- dr_3 \text{REALINT}(t) - d\text{PLAND}(t) - dc_2 \text{KNPLR}(t-1) \end{aligned} \quad (28)$$

where $d=1/c_1$.

In summary, the rate of new planting is related positively to the average revenue on existing planted areas, negatively to the discount rate, negatively to the price of land and negatively to the ratio of newly planted area to the old area. The variable PLAND is actually omitted from the estimated equation because of lack of data, but theoretically it should be present. Its inclusion will capture the external adjustment costs that are likely to be important for the sector as a whole¹⁷.

Two measures of the rate of new planting, NPBAHR and NPBAHR2, move

¹⁶ It is assumed that there is an interior solution for the rate of new planting.

¹⁷ The seriousness of the misspecification ensuing from the omission of the price of land will be case dependent, being the greater when area expansion nears the limit of suitable available land.

synchronously and the regression results for the two are also rather similar, except that residual serial correlation is a more serious problem when the dependent variable is NPBAHR.

As an estimate of newly installed capacity relative to total capacity, two measures have been tried. The first is simply the ratio of area planted after 1966 to the total area planted, denoted KNPLR, a slight variant of this being KNPLR2 where the divisor was OLDAREA. The second measure is NEWCAPR2, the estimated proportional contribution to total cocoa production due to the area planted since 1966. This is based on the potential production calculations alluded to earlier. The regression results using the different variants are broadly similar but those based on NEWCAPR2 are marginally superior in terms of statistical fit.

The estimated equations reported here incorporate a small variation on equation (27) above. The latter may be properly interpreted as an equation for planned rate of new planting. Allow the actual rate to differ from the planned rate by an amount that depends upon the percentage error of price expectation, denoted by CHPRI, which in the present case is simply the percentage change in PRICOCO between current and last period. That is, price

TABLE 7: Basic new planting equation

Dependent variable is NPBAHR2

18 observations used for estimation from 1968 to 1985

Regressor	Coefficient	T-Ratio
CONS	-.0163	3.4623
PRICOCO(-1)	.0735x10 ⁻³	5.2300
PRICOCO(-2)	.0437x10 ⁻³	2.6948
CHPRI	.0117	2.2021
REALINT	-.104x10 ⁻²	-10.0122
NEWCAPR2(-1)	-.0198	-1.9917

R-Squared	.9663
F-statistic F(5, 12)	68.7542
R-Bar-Squared	.9522
S.E. of Regression	.0070318
Residual Sum of Squares	.5934x10 ⁻³
Mean of Dependent Variable	.0369
S.D. of Dependent Variable	.0322
DW-statistic	1.6761

Diagnostic Score (LM) Test Statistics

A:Serial Correlation	CHI-SQ(1)= .2901
B:Functional Form	CHI-SQ(1)= .2783
C:Normality	CHI-SQ(2)= .8643
D:Heteroscedasticity	CHI-SQ(1)= .7206

TABLE 8 : Tests for Non-Nested Models of New Planting

Dependent variable is NPBAHR2

Regressors for model M1: CONS, PRICOCO(-1), PRICOCO(-2), CHPRI, REALINT, NEWCAPR2(-1)

Regressors for model M2: CONC, AREVPROD(-1), AREVPROD(-2), REALINT, CHPRI, NEWCAPR2(-1)

Test Statistic	M1 against M2	M2 against M1
COX-PESARAN	-.6627	-1.4303
ADJUSTED COX-PESARAN	-.4068	-.9602
DAVIDSON-MACKINNON J-Test	.9022	1.4457
ADJUSTED JA-Test	.1700	.4942
Model M1: DW	1.6761	
	R-Bar-Squared	.9522
Model M2: DW	1.5614	
	R-Bar-Squared	.9482
Akaike's Information Criterion of M1 versus M2= .7343 favours M1		

TABLE 9 : Productivity Equation for OLDAREADependent variable is **LOLDPROD**

18 observations used for estimation from 1968 to 1985

Regressor	Coefficient	T-Ratio
CONS	-2.8642	-6.3135
TR66	.0206	2.5136
LPRICOC0(-2)	.3905	4.4258
R-Squared	.7924	
F-statistic F(2, 15)	28.6345	
R-Bar-Squared	.7648	
S.E. of Regression	.1483	
Residual Sum of Squares	.3298	
Mean of Dependent Variable	-.4164	
S.D. of Dependent Variable	.3057	
DW-statistic	2.2468	

Diagnostic Score (LM) Test Statistics

A:Serial Correlation	CHI-SQ(1)=.8410
B:Functional Form	CHI-SQ(1)=.0372
C:Normality	CHI-SQ(2)= .2994
D:Heteroscedasticity	CHI-SQ(1)= .0424

expectations are assumed to be based linearly on the previous period's price. A priori, a positive change will provide an incentive to raise the rate of new planting and a negative change to reduce it.

Using non-nested tests, the specifications based on AREVPROD and either NEWCAPR2 or KNPLR2 , which were generally very similar, were compared with the results obtained with PRICOCO(-1) and PRICOCO(-2) (Table 7) replacing AREVPROD(-1) and AREVPROD(-2), respectively. The tests given in Table 8 favor the model based on PRICOCO.

Whereas the variables AREVPROD and PRICOCO are highly correlated, the regression of AREVPROD on PRICOCO leaves a substantial unexplained variance essentially because the former depends by definition on the average yield of OLDAREA, which has shown very substantial variation. If, however, the relevant variable is the expected yield on new area, which may differ from that on OLDAREA, then the final choice of equation can be rationalized.

The results presented in Table 7 show that all explanatory variables have t-ratios of about 2.0 or greater. The price and the interest rate effects are precisely measured and have the a priori expected signs. The R-bar-squared statistic has a value of .9522 and the diagnostic tests presented in the lower part of Table 7 are all satisfactory. The CUSUM and CUSUMSQ plots were examined ; the former deviates markedly from the zero axis suggesting that at least some of the estimated coefficients may not be robust. The recursively estimated coefficients plotted in Figures 14 through 18 and these suggest that the coefficients of NEWCAPR2(-1) and CHPRI are

relatively the least robust¹⁸.

Price elasticity of new planting : The estimated short-run elasticity of new planting with respect to price measured at the sample means is 1.60 ($= 0.1172 \times 10^{-3} \times 342.42 / 0.0369$), about the same as the replanting elasticity. However, the dynamics of replanting are a great deal more complex and there is considerable internal evidence that the price response of replanting is somewhat nonlinear.

Interest elasticity : The interest rate elasticity measured at the sample mean values is 0.42 - a value very similar to that obtained for replanting. This effect is interpreted as a cost of capital type effect. From 1973 through 1985 the real interest rate was negative and between 1973 and 1980 it was for the most part declining reaching about -68% in 1980, a decline of almost 60 points over the previous two years. The estimated net direct effect of such a decline would be to add about 12180 hectares of new planting, thereby strongly counteracting the negative contribution over this period from the declining average revenue per hectare. It is clear that the factors that contributed to low real interest rates caused a very considerable growth in cocoa new planting during the 1970's¹⁹.

¹⁸ Generally, the t-ratios on the estimated coefficients provides a good guide to the robustness of the coefficients to variations in the sample size.

¹⁹ The empirical analysis of new planting has been carried out without including the theoretically relevant price of cocoa land. Even if this were not a significant omission in the sample period, such may not be the case in the future so that an extrapolation based on the estimated equation should be done with care.

VI : SUMMARY AND CONCLUSIONS

Specifications for replanting and new planting derived from a cost of adjustment model of investment have been estimated and tested extensively in this paper. They stand up well to a battery of specification tests and several key coefficients are robust.

The detailed and the broad conclusions of this paper support the importance of real price of cocoa as a key determinant of both replanting and new planting. Lest such a conclusion should be thought obvious, note that the channels through which this effect operates is perhaps more complex in the case of replanting than new planting. For the latter the short run response may be small, whereas for the former it is estimated to be negative. The long run response of both is estimated to be positive. Though elasticity estimates have been provided in the text, they must be interpreted with care both because of the small sample analyzed and the nonlinearities involved.

The analysis of replanting has been conditioned on the productivity of the pre-1966 planted area. But the latter is an endogenous variable. The average productivity of this area has shown considerable rise since 1966, but the reasons for this change do not appear to have been fully documented. Whether replanting will be stimulated in the future depends both on the movements in the real price of cocoa and the exogenous component of changes in average productivity.

Evidently the low real interest rates of the 1970's and early 1980's have stimulated new planting and also replanting. The strong collinearity between the interest subsidy provided by CEPLAC to replanters between 1977 and 1984 and the real interest rate has prevented a clear quantitative

conclusion about the effect of this subsidy, though its qualitative effect seems to have been as expected a priori. By lowering the real interest even below the prevailing level which was already low, the subsidy reinforced that effect.

The surge in new planting during the last two decades has implications for future new planting. The Brazilian cocoa orchard is now considerably younger than in 1966, and the consequent increase in its production potential reduces the need for both new planting and replanting. A sharp decline in the yield of the pre-1966 planted area and/or the depletion of land suitable for new planting may generate new incentives for replanting. These are issues for future investigations.

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FIGURE 1 : LOG OF BHIA TOTAL PRODUCTION ('000 MT)

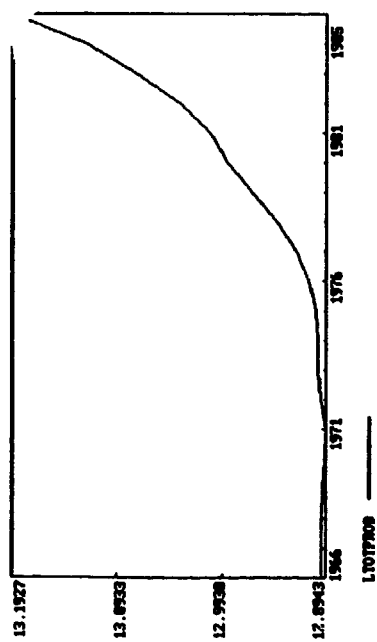


FIGURE 3 : NEW PLANTING OF COCON IN BHIA IN HECTARES

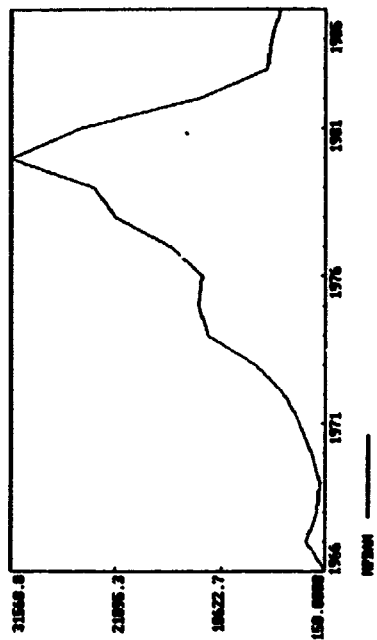


FIGURE 2 : LOG OF TOTAL AREA UNDER COCON IN BHIA

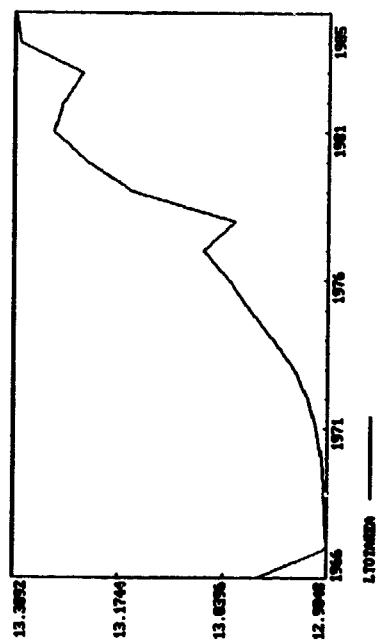


FIGURE 4 : NEW PLANTING DIVIDED BY TOTAL AREA (MPHAKH) ON OLAMBA

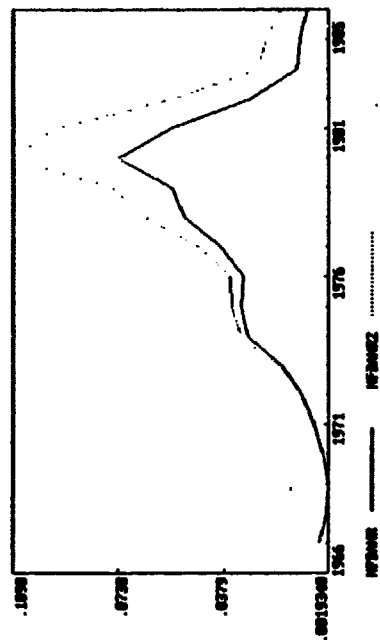


FIGURE 5 : RATIO OF REPLANTING TO NEW PLANTING

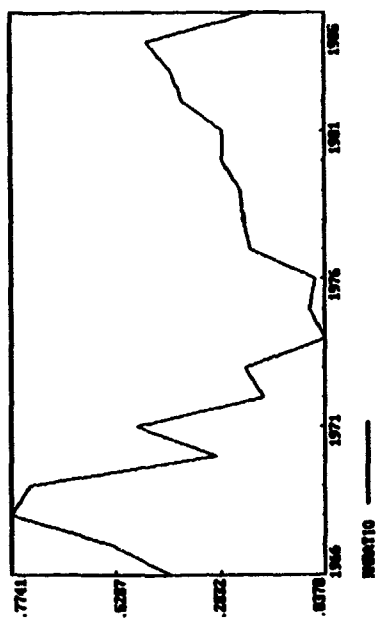


FIGURE 7: LAG OF ESTIMATED YIELD ON PRE-1966 PLANTED AREA

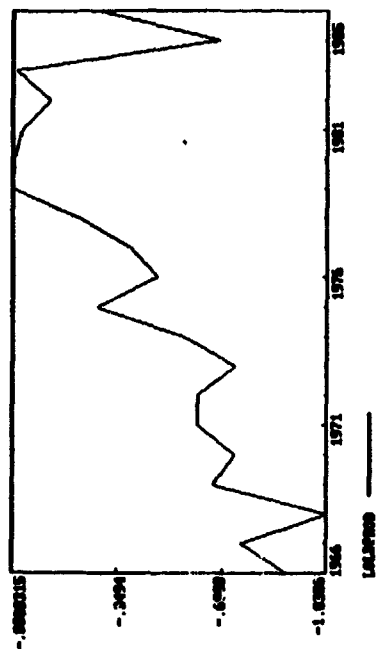


FIGURE 6: RATIO OF PRE-1966 AREA TO TOTAL PLANTED AREA

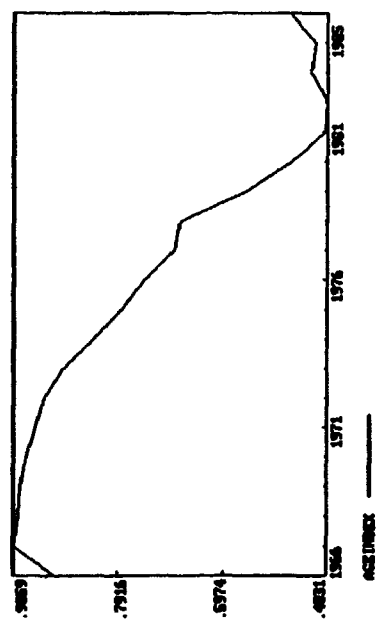


FIGURE 8: LAG OF REAL Cacao PRICE

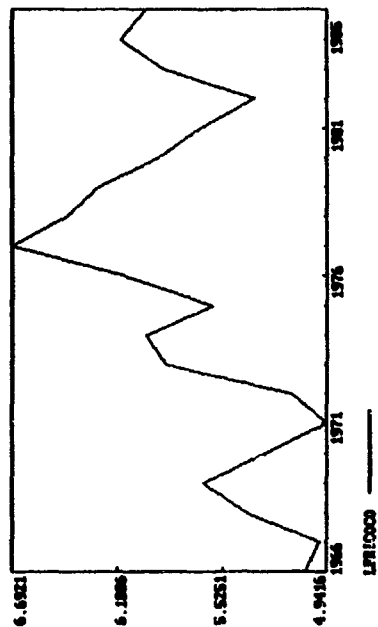


FIGURE 9

REPLANTING EQUATION

Plot of the Coefficient of $AREUPROB(-1)$ based on recursive regression

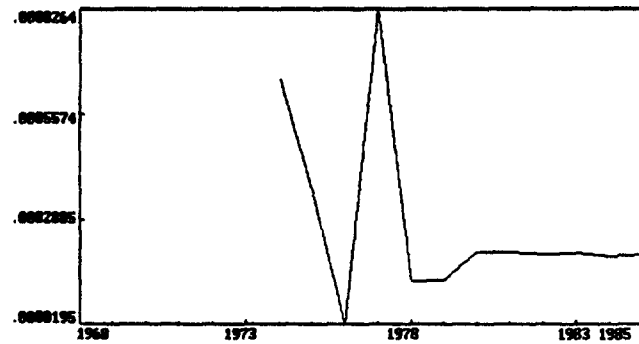


FIGURE 10

REPLANTING EQUATION

Plot of the Coefficient of $REALINT(-1)$ based on recursive regression

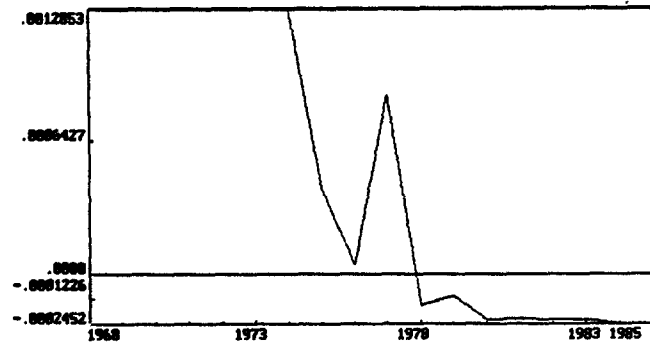


FIGURE 11

REPLANTING EQUATION

Plot of the Coefficient of $OLDPROB(-1)$ based on recursive regression

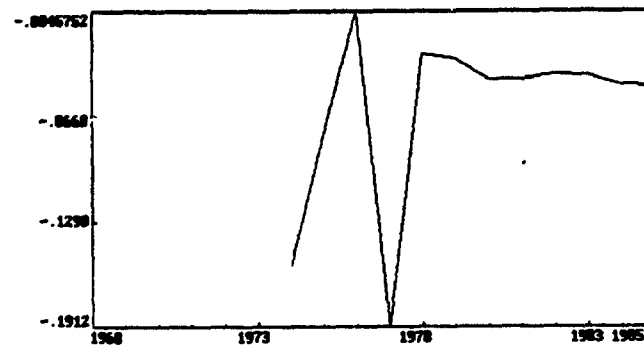


FIGURE 12

REPLANTING EQUATION

Plot of the Coefficient of $PRICOC(-1)$ based on recursive regression

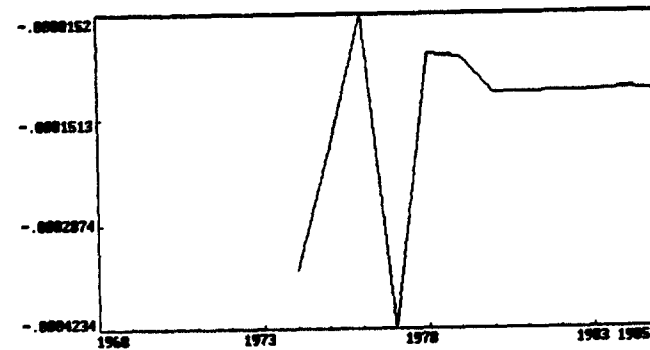


FIGURE 13 REAL SUBSIDY RATE/IN OF OLD AREA AND REAL INTEREST RATE

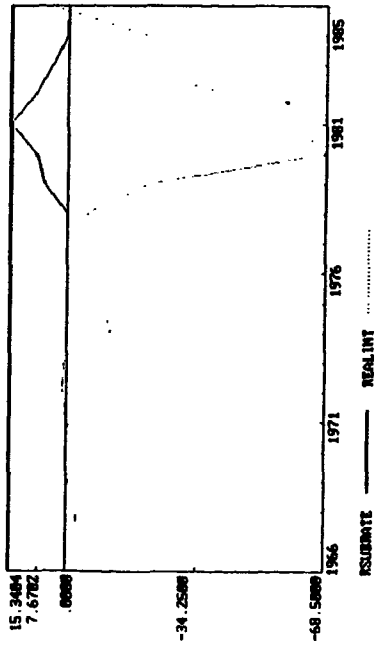


FIGURE 14

NEW PLANTING EQUATION

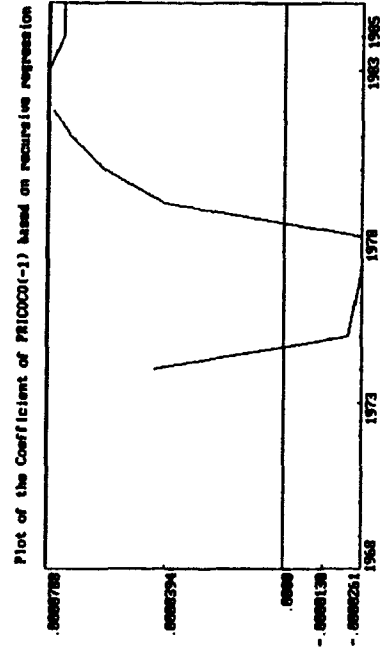


FIGURE 15

NEW PLANTING EQUATION

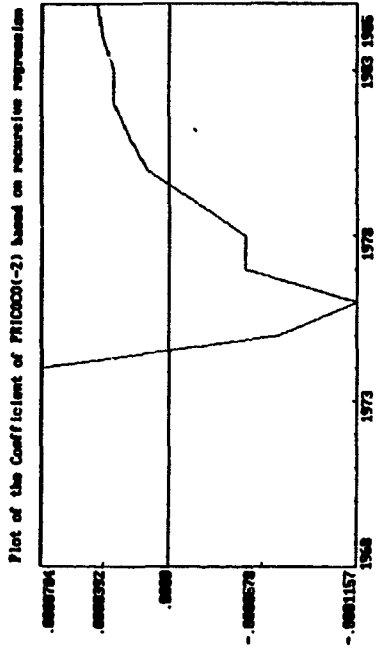


FIGURE 16

NEW PLANTING EQUATION

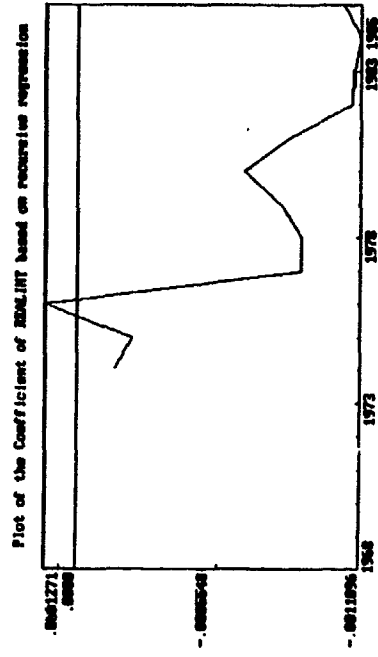


FIGURE 17
NEW PLANTING EQUATION

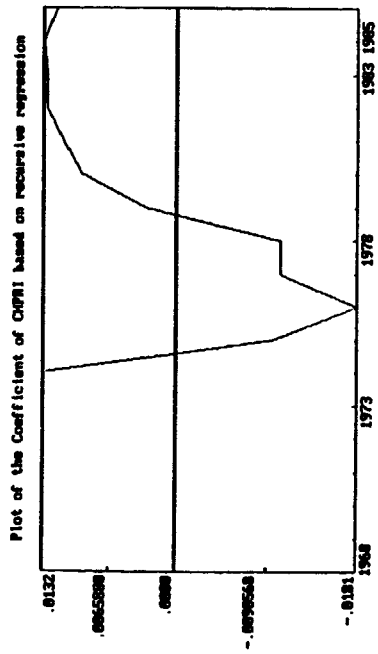
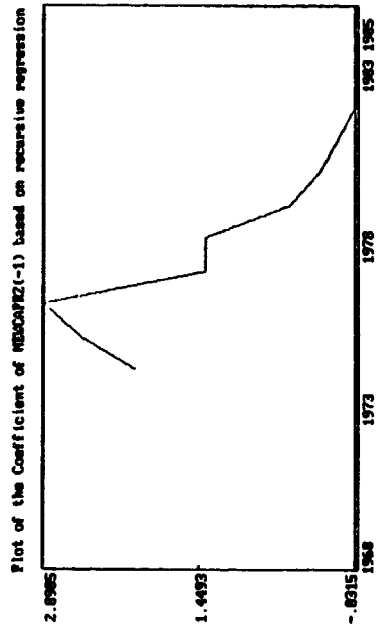


FIGURE 18

NEW PLANTING EQUATION



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